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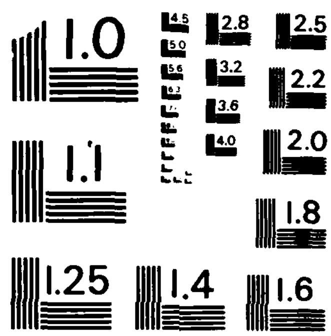

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IMPLEMENTATION OF A MICROCOMPUTER-BASED TESTING SYSTEM IN A MILITARY TRAINING ENVIRONMENT

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November 1985

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A computerized testing system was installed on an experimental basis at the Basic Electricity and Electronics School of the Naval Training Center in San Diego. The system consisted of a network of IBM Personal Computers running a slightly modified version of the commercially available MicroCAT(tm) Testing System. It was configured to fit transparently into the school's computer-managed instruction system. After a few minor adjustments and a few added features, the system met its goal of paralleling the paper-and-pencil version of the tests with a minimum of change in standard testing procedures. Now in place, the system provides a base on which diagnostic testing research can begin.

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ABSTRACT

A computerized testing system was installed on an experimental basis at the Basic Electricity and Electronics School of the Naval Training Center in San Diego. The system consisted of a network of IBM Personal Computers running a slightly modified version of the commercially available MicroCAT^{tm} Testing System. It was configured to fit transparently into the school's computer-managed instruction system. After a few minor adjustments and a few added features, the system met its goal of paralleling the paper-and-pencil version of the tests with a minimum of change in standard testing procedures. Now in place, the system provides a base on which diagnostic testing research can begin.

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INTRODUCTION

Achievement testing takes up a substantial portion of a trainee's time in a self-paced military service technical school because continual assessment of the trainee's skills is necessary to pace the instruction. Obviously, anything that can be done to make testing more efficient or to extract better information from the testing process will enhance the quality of training. Several forms of computerized testing, including computerized adaptive testing (Weiss, 1982, 1985) and computer-based diagnostic testing (Tatsuoka & Tatsuoka, 1983), offer the promise of such an improvement.

Computer-based instruction and testing in the service schools requires reliable, inexpensive computer equipment that can handle a variety of presentation forms. Among the forms such equipment must handle are standard computer-based instruction and conventional, adaptive, or diagnostic testing. Although a variety of software systems for computer-based instruction are available, very few software systems are available for implementing adaptive or diagnostic testing. The MicroCAT^{tm} Testing System (Assessment Systems, 1984) is a generic testing system that can be used for most forms of testing and many forms of computer-based instruction.

The development of the MicroCAT system was partially supported by funds from the Office of Naval Research (ONR). A major objective of ONR in supporting this development was to provide a testing system to meet the needs of the training and achievement-testing environment. To test its effectiveness in this environment, MicroCAT was implemented in a Navy Training Center as a means of introducing diagnostic testing into one of the service technical schools.

The system was implemented at the Basic Electricity and Electronics (BE&E) School at the Naval Training Center in San Diego, California. The overall implementation plan was to introduce a computerized testing system into the current testing process and, once this system was in place and tested, to extend the program to diagnostic testing. This report describes the design and initial implementation of this system.

DESIGN OF THE TESTING SYSTEM

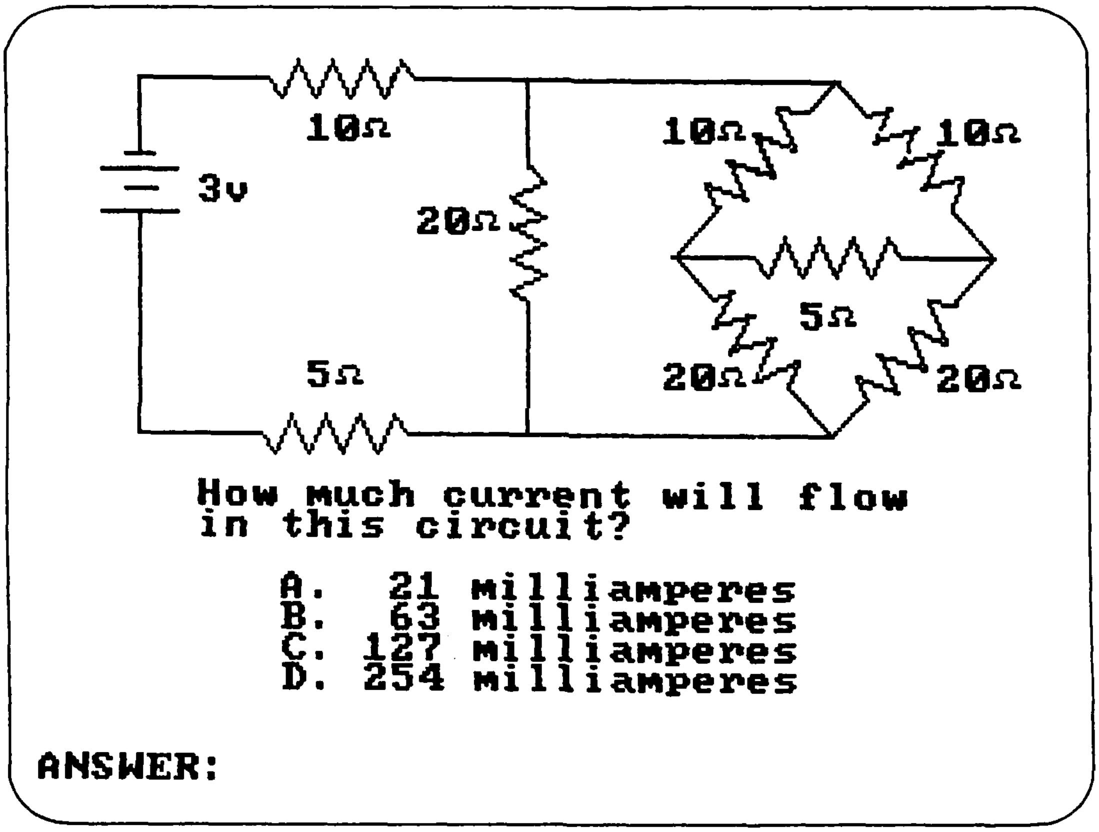
When this project began, the design of the MicroCAT Testing System was nearly complete and many of the MicroCAT programs had been developed. The objectives of the design of the testing system for the BE&E School were: (1) to assess the testing needs of the school, (2) to expand the MicroCAT system to allow the strategies for diagnostic testing to be implemented, and (3) to integrate the system into the testing environment and the computer-managed instructional system that were already in place at the school.

System Requirements

Students at the BE&E School are tested approximately once a day. The student studies a particular subject and then takes a test on that subject. The

achievement tests used in the BE&E curriculum contain 8 to 50 questions on basic electricity and electronics knowledge. Typically they consist of some form of graphic (e.g., a schematic or a chart) and a question, often using special symbols (such as an omega for ohms). Figure 1 shows a sample item (not actually used in the BE&E curriculum) on resistance analysis. To solve this problem, the examinee must know how to apply Ohm's law and must either recognize that the bridge on the right of the schematic is balanced (thus providing a computational shortcut) or apply an appropriate network theorem to determine the overall resistance, and thus current, in the system.

Figure 1. Sample Electronics Item



To take a test in the conventional paper-and-pencil format, a student reports to a testing room and is assigned a microfiche card containing the test. The student then goes to a testing carrel containing a microfiche reader, loads the test into it, and responds to the questions by marking an optically scannable answer sheet. After the student completes the test, he or she puts the answer sheet into an optical scanner, which reads the answer sheet and transmits the information to MIISA, the computer-managed instruction system running on a mainframe computer in Memphis, Tennessee. MIISA determines that the test the examinee took was the proper one, scores it, reports the results, and updates

the student's record in the database. The student receives the reported results on a printing computer terminal connected to the optical scanner. This report tells the student his or her score and what test to take next.

During the initial phases of implementation of the computerized testing system, students could take tests using either the computerized system or the conventional microfiche cards. The computerized tests had to be psychometrically comparable to the microfiche tests because all scores would be interpreted on the same scale. It was important that the tests be psychologically comparable as well, because if students perceived a difference in the difficulty of the tests, either real or imagined, they might avoid the form they considered to be more difficult or troublesome. Three factors that contribute to the psychological comparability of the forms are: (1) speed of system response to the examinee, (2) fault tolerance during system failures, and (3) support of standard test-taking strategies. To avoid giving the examinee the impression that the computerized version is slower than the conventional version, a goal for the maximum system time between the examinee's response and the presentation of the next item was set at less than five seconds. It is also important for examinees to feel confident that their work will not be lost because of equipment failure. And finally, a major test-taking strategy that must be supported is the examinee's ability to skip items and then return to them at the end of the test.

The computerized testing system also had to fit into the existing computer-managed instructional system without requiring any programming on the part of the Navy. This essentially meant that no changes in the testing process could be made that would be detected by MIISA.

Finally, the system had to be able to handle special cases. An example of a special case in the traditional testing mode would be a mis-scanned answer sheet that failed to give credit for all correct responses. Another would be the loss of an examinee's record after its receipt had been acknowledged by MIISA. In the conventional testing format, special cases are handled by the test proctor, who interacts with MIISA on the printer terminals used to return examinee test results. A similar means of proctor intervention had to be made available with the computerized testing system.

Analysis of the Systems

MIISA: The Navy's Computer-Managed Instruction System

All instruction and testing at the BE&E School is managed by MIISA, the program that assigns and scores tests and tracks student progress throughout the entire course of study. It is a very large program running on a mainframe computer at a central computer installation. Because of its size and distance from the BE&E School, it is very difficult to make any changes to the program. Therefore, the computerized testing system had to use existing MIISA interfaces. The most convenient interface was with the printer terminals through which scanned test responses are transmitted and score reports are received.

The printer terminals used are General Electric Terminet terminals. These terminals contain sufficient intelligence to read the data from the optical scanner, add a header of approximately 20 characters, and transmit the transaction to MIISA. Data are transmitted from the Terminet through a standard RS232 serial port. The data are communicated through a 1200-baud modem to a local concentrator and then transmitted to MIISA at 9600 baud.

The transactions sent to MIISA are all single lines of ASCII characters terminated with a carriage return. Data returned from MIISA a e score reports formatted for the Terminet's printer. Among the transactions of interest to this project are score reports and requests for tests to be taken. It was apparent that a convenient way to connect to the existing system was to emulate the Terminet terminals, sending proper Terminet transactions and receiving score reports.

The MicroCAT Testing System

The MicroCAT Testing System was designed to be a self-contained system for developing, administering, and analyzing adaptive tests. The system is packaged into four subsystems: the Development Subsystem, the Examination Subsystem, the Assessment Subsystem, and the Management Subsystem. The programs available in each of these subsystems are shown in Table 1.

The Development Subsystem contains programs for entering and editing test items consisting of text and graphics and for arranging those items into tests using a number of conventional and adaptive testing strategies. Tests are specified in MCATL, an authoring language designed especially for specifying tests. (This specification may also be accomplished by filling in blanks in pre-defined strategy templates.) MCATL is compiled to an intermediate form of code that can be executed quickly during the testing process.

The Examination Subsystem administers the tests. The programs in this subsystem read the test specification instructions (the intermediate code file generated by compiling the test specification), present the test items, accept the examinee's responses, score the responses, and report the results in a data file.

The Assessment Subsystem contains programs for analyzing tests that have been administered. One program, ASCAL, estimates item response theory (IRT) item parameters. Other programs in this subsystem reformat data for analyses, perform conventional item analyses, evaluate characteristics of item pools, and perform test validation analyses.

The Management Subsystem is intended for use with a network of testing stations. Some programs in the Management Subsystem allow a proctor to monitor testing at a number of testing stations from a single terminal; others store individual examinee data in a master data file.

Table 1. MicroCAT Components

Development Subsystem	
BANK:	Enters and edits text and graphics items
MAKEFONT:	Generates special-purpose character sets
CREATE:	Creates tests using pre-defined templates
EDIT:	Enters and edits MCATL test specifications
COMPILE:	Compiles test specifications
Examination Subsystem	
TESTONE:	Tests one examinee and writes the score to a file
TESTMANY:	Tests examinees repeatedly and writes scores to a file
Assessment Subsystem	
COLLECT:	Collects and formats item response data
ANALYZE:	Performs conventional item and test analyses
ESTIMATE:	Estimates IRT item parameters using ASCAL^{tm}
EVALUATE:	Pre-evaluates a test's potential using IRT
VALIDATE:	Performs test validation analyses
Management Subsystem	
RESERVE:	Reserves disk space for communication
PROCTOR:	Proctors test administration from a command station
RETRIEVE:	Retrieves data from the master data file

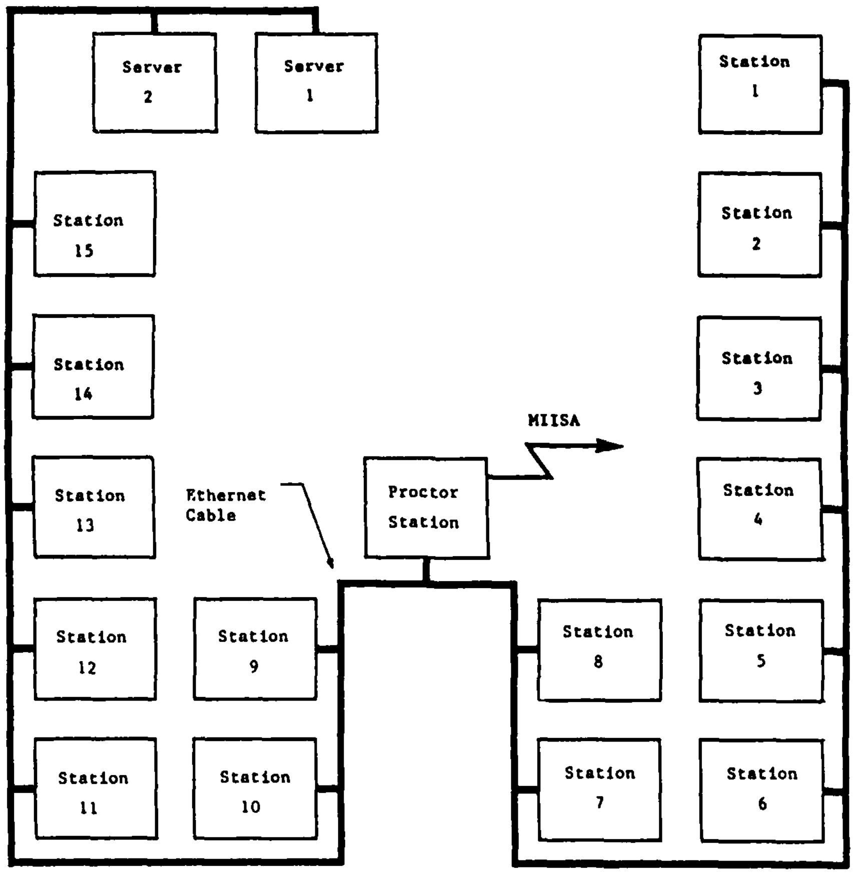
Two substantial modifications to the MicroCAT system were planned to incorporate it into the Naval Training Center (NTC) testing environment. At the time this implementation was planned, the MicroCAT system had no facility by which an examinee could skip an item and later review it, or change responses to any items previously administered. Such capabilities are not typically allowed in adaptive testing. However, to maintain psychological comparability to the existing conventional testing process, such an addition was necessary. The second addition was the incorporation of communication facilities so that the MicroCAT Testing System could communicate with MIISA. The planned approach to this was to enhance the proctoring program so that it could communicate with MIISA by emulating the General Electric Terminet terminals and the standard transaction protocols.

Integrating the Resources

The MicroCAT Testing System runs on IBM Personal Computers. Each individual testing station has one such computer. An IBM Personal Computer consists of three major components: a monitor, a system unit, and a standard keyboard with several additional function keys added at each end.

For the fault-tolerant testing system required for the NTC implementation, 18 IBM Personal Computers were connected via an EtherNet local area network. A diagram of the system is shown in Figure 2.

Figure 2. Structure of the NTC Implementation



The two network servers shown at the top of Figure 2 contain the tests that are administered and the data that are collected. The two servers in the NTC system are IBM PC-XT computers. Each has 256 kb of RAM memory, one 360-kb diskette drive, and one 10-mb hard-disk drive. Each server contains all of the tests to be administered. In normal operation, each server serves half of the testing stations. If either of the servers fails, the other one is capable of handling the entire testing system.

All remaining terminals on the network are IBM PCs with 192 kb of RAM memory and a single diskette drive. The single diskette drive contains only those programs necessary to link each terminal into the network and the current examinee's responses for test recovery in case the testing station fails.

Two of the testing stations are configured to function as proctoring stations. In addition to the standard testing system hardware, they contain a serial port to communicate with MIISA and a printer to print test results. In normal operation only one proctoring station is used; the other is used as a standard testing station and is available as a backup if the proctoring station fails.

IMPLEMENTATION OF THE SYSTEM

Description of the Initial System

The initial system was organized functionally as described above and in Figure 2. To operate the system, the test proctor first has to start the network servers by turning on the power, entering the date and time, and making a single keystroke to start the network server in a normal fashion.

After starting the servers, the proctor turns on the proctor station and all of the testing stations. All of these terminals automatically link into the network and establish a connection with the proper server. The server to which each testing station connects is determined by data contained on the diskette within the testing station.

The proctoring station presents a message asking the proctor if the test request queue should be cleared. In the case of a normal start, this is always done. Only in unusual circumstances, such as recovery after a power failure, would the proctor not clear the test request queue. The communications link with MIISA is automatically established by turning on the modem. At this point the system is ready for operation.

When an examinee arrives to take a test, the proctor assigns him or her to one of the available testing stations. Each available testing station displays the message that the examinee should enter his or her Social Security number and press the return key. When the examinee does this, the Social Security number is passed through the network to the server and from the server to the proctoring station, where it is formatted into a transaction asking MIISA what test should be assigned to the examinee. MIISA then responds with a report, and the program running on the proctoring station extracts the test identifier from that report. It passes the test identifier back through the network to the testing station where the examinee is waiting for a test. This process typically takes between 5 and 10 seconds.

As items are administered at the testing station, each response is edited to ensure that it is valid. When the examinee finishes a test, the response record is passed through the network to the proctoring station, which formats it into a transaction and transmits it to MIISA. MIISA then scores the test, updates the

examinee's course record, and transmits a report to the proctoring station. The proctoring station then passes this report to the system printer, from which the examinee obtains his or her score report. The testing process is complete at this point.

Initial Evaluation

For the most part, the initial system ran without error. Students taking tests on the system were reliably tested and always received proper reports from MIISA. However, the Navy chiefs in charge of the testing process noticed two potential difficulties with the system. First, they determined that it was possible for a student to run two terminals simultaneously. By doing this, a student could preview the items on one station and then answer them on a second station. Since there was no feedback given about the correctness of responses, there was really no advantage to be gained from doing this, but it was nevertheless of concern to the chiefs. The second potential problem was that students could reset their testing stations with several combinations of keys (e.g., **control-c**, and the system reset combination of **control-alt-delete**).

System Revisions

To alleviate the first problem identified in the initial evaluation, a lockout buffer was incorporated into the proctoring station to prevent a student from operating more than one station at a time. When a student logs into the system, his or her Social Security number is kept in a buffer and is not deleted until he or she completes the test. If the student tries to log in at another station, a message appears informing him or her that this is not allowed, and the proctor is alerted at the proctoring station.

To solve the reset problem, most of the control key combinations that could reset the testing station were disabled. However, the **control-alt-delete** combination is buried deep in the hardware of the IBM Personal Computer as the system reset and there is no way to disable it from the software. This was considered a relatively minor problem, however, because it is extremely unlikely that a student would hit this combination of keys accidentally, and anyone who was determined to reset the station could always do so by turning the power off, even if the **control-alt-delete** combination could have been disabled.

Additional Features

Several additional features were added to the system, some of which had not been initially intended. The first was a modification to allow students to take remedial tests on the computerized testing system. (Remedial tests are for students who fail a particular portion of a test and must retake only that portion after additional study.) In the microfiche mode, the student simply answers the questions in that section and leaves all of the other sections on the answer sheet blank. If the student accidentally answers items in any other section of the test, the test record is rejected by MIISA. To allow remedial examinations in the computerized testing system, two modifications were made. First, standard testing mode was altered to allow students in remedial mode to

skip sections of the test. Remedial test sections without any responses are simply ignored by MIISA. Another modification was necessary to solve the problem that occurred when an examinee accidentally answered an item in the wrong section, causing MIISA to reject the entire test record. In this case, the response vector is analyzed at the proctoring station, and any section in the test that has some but not all of the items answered is completely blanked as if the examinee had answered no items in that section. That section is then ignored by MIISA, and only the section that has all items answered is scored. With these modifications, the computerized mode is virtually identical to the paper-and-pencil mode of remedial testing.

A second feature that was added to the system was the capability to retransmit an examinee's test record directly from the proctoring station. Occasionally, the MIISA system would accept a test record and produce a report but then lose the test record. The proctors then had to re-enter the record by hand using the communication capability provided in the proctoring station. To solve this problem, a facility was incorporated into the proctoring program that would retransmit the entire test record from the recovery file on the testing station's diskette.

Because the data collected by computer administration were to be analyzed by the University of Illinois, a data transfer scheme was needed. The MIISA link is a real-time link in that testing waits for communication. Transferring the data to the University of Illinois, on the other hand, had to be done only when the data were needed or when the disks on the NTC network were full. A system was developed whereby the test proctor periodically dumped the data from the system disks to two sets of diskettes, one for the University of Illinois and one for backup. After dumping the data, the proctor was instructed to mail one set to the University of Illinois and to keep the backup set until receipt was confirmed. The data on the system disk were erased after the diskettes were made. Except for the difficulty of getting the proctor to make the data diskettes on a regular basis, this scheme worked well.

Testing has not been interrupted because of any system problems. It was interrupted for several weeks, however, by the implementation of new versions of the tests. The frequent changes in tests, which had not been anticipated when the system was installed, required frequent communication with the University of Illinois. It had been intended that the University of Illinois would do the test development and then either manually install the tests in the San Diego system or mail complete test files with installation programs to be run by the proctor. However, as the test changes became more frequent, it became apparent that it would be more efficient for NTC personnel to make the changes themselves and install the tests.

Test development in the MicroCAT system is a three-stage process. First, the items are authored using the system's Graphics Item Banker. Then the test is specified using an authoring language. Finally, the authoring language is compiled, a process that reformats the items and processes the instructions in a manner that allows items to be presented rapidly. Implementing a test in the NTC system required the further step of copying the compiled test onto the appropriate disk volume.

NTC test administration personnel mastered the process with relative ease. However, a few problems did arise. One problem was that if diskettes were swapped while the item banker was running, a bank would be destroyed. Although this problem is easily circumvented by not swapping diskettes, this solution was obviously not optimal. A utility program that could recover a bank destroyed in this manner was developed.

A second problem that was encountered was that two people sharing a disk volume using the Ethernet network from 3Com can, under certain circumstances, destroy each other's work. For example, NTC personnel destroyed an item bank by writing portions of a memo over it. Fortunately, the new program was able to restore most of what was lost.

EVALUATION OF THE SYSTEM

The MicroCAT Testing System was implemented at the BE&E School to provide a vehicle for diagnostic testing and to evaluate the MicroCAT system in a full-scale operational testing environment. In general, the MicroCAT system has performed admirably. To date, approximately 2,400 items have been banked for this application. From these, approximately 50 different tests have been implemented, and approximately 1,500 tests have been administered. Informal evidence from the BE&E School suggests that the system is fast enough for all testing needs, that examinee's perceive it as psychologically parallel to the microfiche form of testing, and that it is adequately fault-tolerant. Although the local testing system rarely fails, the capability to retransmit data if MIISA loses the original transmission has been very valuable.

As an evaluation site for the MicroCAT system, the NTC environment has been less than optimal. To date, only the conventional testing capabilities of the MicroCAT Testing System have been evaluated to any degree. The considerable power for adaptive test administration and analysis that is a major strength of the MicroCAT system has not been evaluated at all in the NTC implementation. Fortunately, some of the commercial sites in which the MicroCAT Testing System is used have provided more thorough tests of the system's adaptive testing capabilities. Even there, however, it may be several years before all of the extensive capabilities of the MicroCAT Testing System are given a challenging test.

FUTURE PLANS FOR DIAGNOSTIC TESTING

The MicroCAT Testing System has not yet been used for diagnostic testing; insufficient data have been collected to allow diagnostic tests to be developed. The programs are ready to implement such testing, however.

MicroCAT does not include the diagnostic testing strategies because they are still under development and are not widely used. Diagnostic testing will be implemented using the custom interface included in MicroCAT. The custom interface allows users to link FORTRAN or Pascal procedures to MicroCAT. New scoring procedures can be included this way and are treated by MicroCAT in a manner similar to the standard scoring procedures (i.e., they are executed

each time a score is needed). Similarly, test execution can jump directly to a custom procedure through the execution of a procedure call in the test specification.

Using these custom interfaces, programmers at the University of Illinois will develop and revise the diagnostic procedures as needed. No modification to the MicroCAT Testing System itself will be required.

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